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Low-lying Yrast states in ^{218}Th

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Résumé. — Dans la réaction ^{206}Pb(^{16}O, 4n)^{218}Th, des rayonnements γ ont été observés en coïncidence avec les particules α de la décroissance de l'état fondamental. Une proposition de schéma de décroissance du ^{218}Th est faite.

Abstract. — Gamma-rays in coincidence with the α-particles from the decay of the ground-state of ^{218}Th have been observed in the ^{206}Pb(^{16}O, 4n) reaction. A tentative decay scheme of ^{218}Th is proposed.

Nuclei in the vicinity of the doubly closed ^{208}Pb core ($N = 126$, $Z = 82$) have attracted a great deal of experimental and theoretical work. For nuclei with both proton and neutron particles outside this core, there is however a lack of experimental information on Yrast states. This is due on one hand to the difficulty of finding suitable target-ion beam combinations. On the other hand, for elements above radium isotopes ($Z = 88$), the magnitude of the cross-section for transfer reactions is comparable to that of compound nuclear formation, where the fission channel prevails over the fusion-evaporation channel. In that case the background problem encountered in γ-ray in-beam measurements can be overcome for $N = 128$, 129 nuclei by making use of the short lifetime of the α-decaying ground-states. This has been done for ^{218}Th by selecting the γ-rays in coincidence with the α-particles from the decay of the ground state, which has a half-life $T_{1/2} \simeq 0.11$ µs [1, 2].

Excited states in ^{218}Th were produced *via* the ^{206}Pb(^{16}O, 4n) reaction with an incident beam of 92 MeV provided by the Strasbourg M.P. tandem accelerator. The ^{16}O beam was pulsed with a repetition time of 400 ns and the resulting beam bursts had a time spread of about 1 ns. The time reference for the beam bursts was provided by a chevron channel plate array detecting secondary electrons emitted from a carbon foil placed 1 m in front of the target [3]. A 1.8 mg/cm^2 self-supporting ^{206}Pb target was set at an angle of 65° with respect to the beam axis. In such a way, the effective thickness of the target was twice the range for recoiling Th ions and part of the

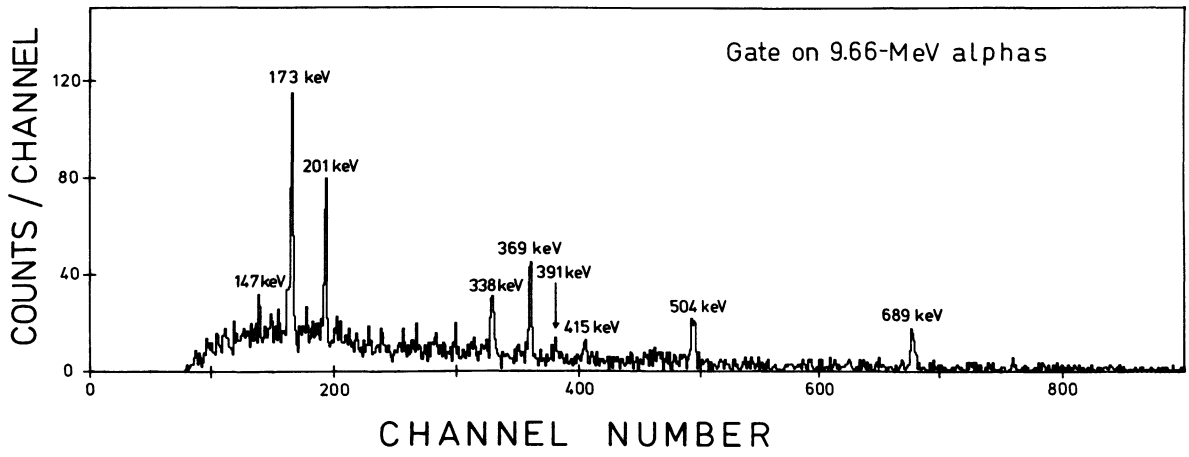

Fig. 1. — Gamma-ray spectrum in coincidence with delayed α-particles from the decay of the ^{218}Th ground-state.

α-decaying nuclei produced by the reaction were stopped in the target. The α-particles were detected with a Si surface-barrier detector of 300 mm^2 area and 200 μm thickness mounted at a distance of 35 mm from the target and an angle of 140°. Gamma-rays were detected in a 9 cm^3 planar Ge(Li) detector, having good timing properties, set at 90°.

A singles α-particle spectrum was recorded in order to observe possible delayed α-particles arising from excited states in ^{218}Th. No such particles with a mean-life greater than 10 ns and an intensity larger than 3 % of the ground-state intensity have been observed. This measurement also yields a value of $T_{1/2} = 125 \pm 5$ ns for the half-life of the ground-state of ^{218}Th, in agreement with one of the previously reported values [1].

Table I. — *Results of the α-γ coincidence measurement*

E_γ (keV) (a)	I_γ (b)	E_γ (a)	I_γ (b)
146.9 ± 1.0	4 ± 2	390.5 ± 1.0	19 ± 6
173.3	44 ± 4	414.5 ± 1.0	25 ± 8
201.2	37 ± 4	504.4	98 ± 15
338.4	57 ± 8	688.8	100 ± 17
369.2	80 ± 9		

(a) Gamma-ray energies are accurate to ± 0.6 keV, unless otherwise indicated.

(b) Gamma-ray intensities are normalized to the 688.8 keV yield.

Gamma-rays in coincidence with delayed alpha-particles of 9.66 MeV emitted by the ^{218}Th ground-state were recorded for 30 hours. The resulting spectrum is displayed in figure 1 and the γ-ray intensities are listed in table I. The strongest γ-transitions observed in ^{218}Th are prompt transitions ($T_{1/2} < 4$ ns) as may be seen in figure 2 which shows the added time distributions of two of the stronger γ-rays with respect to the beam burst. The absence of a measurable lifetime in ^{218}Th explains why, in contrast to other even-AN = 128 isotones [4-6], no long-range α-particles arising from excited states could be observed.

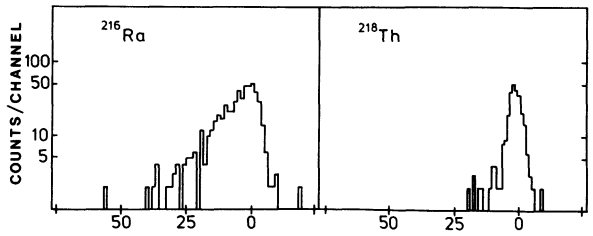

Fig. 2. — Added time distributions with respect to the beam burst for the 338- and 369-keV γ-transitions in ^{218}Th (right part). The left part of the figure shows the added time spectra for the 309-, 315- and 345-keV γ-transitions in ^{216}Ra governed by a 7 ns half-life [7], obtained by gating on the 9.35 MeV α-group from the decay of the ^{216}Ra ground-state.

The production of ^{218}Th in the ^{206}Pb + ^{16}O reaction represents only a very small part of the total cross-section, less than 0.3 % according to both the ^{206}Pb(^{16}O, 4n) and fission cross-section measurements [1, 9]. Therefore, in the present experiment no peaks attributed to ^{218}Th γ-transitions could be observed in singles γ-spectra and this hampered further measurements such as γ-ray angular distributions. However, according to the general trend observed in the excitation energies of the Yrast states in the even-AN = 128 isotones (see Fig. 3) and taking into account the measured γ-ray intensities, a tentative level scheme of ^{218}Th can be proposed, consisting of a cascade of the 369, 504 and 689 keV γ-rays, probably preceded by the 201 keV γ-ray.

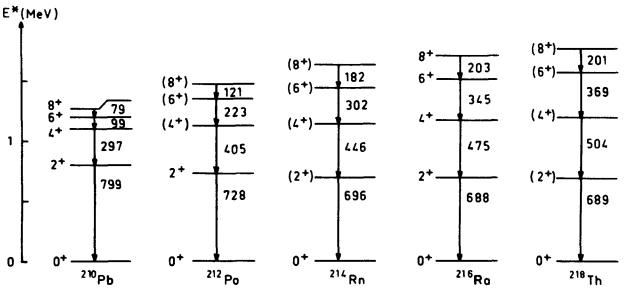

Fig. 3. — Excitation energies of the first 2^+, 4^+, 6^+ and 8^+ states in the N = 128 isotones : ^{210}Pb, ^{212}Po [8], ^{214}Rn [6], ^{216}Ra [4, 7] and the proposed level scheme for ^{218}Th.

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